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Aneurysm Involving the Innominate, the Right Subclavian, and the Right Common Carotid Arteries;

TREATED BY PROXIMAL LIGATURE: DEATH FROM DIRECT EXTENSION OF COAGULATION FROM THE ANEURYSM TO THE MIDDLE CEREBRAL ARTERY.

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A Case of Aneurysm Involving the Innominate, the Right Subclavian, and the Right Common Carotid Arteries.

THE patient, a Royal Marine, was sent to me by Fleet-Surgeon T. D. Gimlette of the Royal Naval Hospital, Plymouth, and was admitted into St. Thomas's Hospital on March 27th, 1902. He was 35 years of age, well-built and muscular, but somewhat ill-nourished. At the root of the neck on the right side was a pulsating swelling and the voice was slightly hoarse. The pulsation was expansile in character. The swelling measured nine centimetres in its longest diameter and extended a little beyond the middle line, displacing the trachea somewhat to the left (see Fig. 1). On auscultation a loud aneurysmal murmur was heard. The aneurysm extended under the manubrium, the right upper part of which was dull on percussion. The longest diameter of the tumour was in an upward and outward direction. Posteriorly it did not reach further than the anterior margin of the posterior triangle of the neck. The bulging of the aneurysm above the sternal end of the clavicle so elevated the skin that the outline of the inner half of the clavicle was lost. The right radial and carotid pulses were smaller than those of the opposite side but were not dicrotic. The right pupil was smaller than the left but was otherwise normal. The right vocal cord moved imperfectly (slowly) but was not paralysed. Some impairment of resonance with increase of voice sound and of vocal fremitus at the spine of the right scapula suggested that there was pressure on the right lung. There was no other evidence of visceral disease and the veins were not enlarged. Dr. S. J. Sharkey kindly examined the patient and reported that there was no evidence of aortic or cardiac disease. The patient complained of considerable pain in the region of the tumour and of frequent hacking cough with slight expectoration. There was nothing in the family history bearing on the case. He had had no serious illness and had never taken much alcohol. There was no clear history of his having had syphilis, but he had been exposed to the infection in 1885 when he contracted gonorrhœa. In the autumn of 1901 he had pain in the neck and slight cough. In January, 1902, he temporarily lost his voice and a week later a swelling was noticed low down on the right side of the neck near the middle line. From the first he had some slight difficulty in swallowing liquid food. A skiagram was taken, but it did not clearly show the outline of the tumour in the chest. The patient was most intelligent and willingly consented to undergo a modified Valsalvan treatment. He remained absolutely quiet and food and drink, especially the latter, were gradually reduced in quantity. Iodide of potassium in large doses was administered.

It was, however, soon evident that the aneurysm was slowly increasing in an upward and outward direction. It was therefore determined to ligate the innominate artery below the aneurysm and also, so as to cut off any regurgitant stream, the carotid artery above it, the aneurysm being supposed to involve the upper end of the innominate, the first part of the right subclavian, and the origin of the right common carotid arteries.

Operation, April 15th, 1902. Chloroform was administered by Dr. Harold Low and I was most ably assisted by Mr. P. W. G. Sargent, the then acting resident assistant surgeon, and by Mr. G. N. C. Shipman, the house surgeon. The shoulders were raised and the head was thrown back so as to place as much of the artery in the neck as possible. The neck was not short and the adoption of this position did not embarrass the breathing. I stood on the patient's left. A median incision was made from the lower margin of the thyroid cartilage to the lower border of the manubrium. The cervical fascia was divided and the adjoining margins of the sterno-hyoids above and the sterno-thyroids below were separated.[1] An inferior thyroid vein required division and one or two other small points were ligatured. The dissection was then continued between the tumour and the trachea which was displaced to the left. The finger passed without difficulty into the superior mediastinum until the arch of the aorta was felt. Then by carefully working towards the right it was soon ascertained that the tumour ceased abruptly a little distance from the aorta and that half an inch of healthy, or at least undilated, innominate artery intervened between the aorta and the tumour The question then arose, Should the manubrium be split and the halves held apart (Milton's method)[2] or should a portion of the bone be removed so as to get a better view of the operation area? The plan adopted (though I believe interference with the manubrium was uncalled for and unnecessary) was as follows. The manubrium was bisected vertically with the saw and chisel and at the level of the upper borders of the second costal cartilages a transverse incision was made in it. Strong hook retractors were inserted in the vertical incision and the two halves of the manubrium were pulled apart. This method has been recommended by Farquhar Curtis[3] and his description was followed in conducting the operation. Separation of the fragments was not, however, obtained to the desired extent and so about half an inch of bone was removed on either side of the vertical incision. After this removal of bone retraction was very effective in exposing freely and directly the region above the arch of the aorta. A forehead electric lamp was a valuable aid as the parts, though freely exposed, are some considerable distance behind the sternum. The vessel was gently cleared for the aneurysm needle and the left innominate vein being pushed downwards, the needle was passed, then threaded with gold-beater's skin ligature (ox peritoneum), No. 4 size, and withdrawn. This was done twice so that four strands of ligature were passed round the artery. They were tied in a stay-knot and the vessel was occluded without injury to its coats. The

[1] See Fig. 211, p. 486, "Ligation in Continuity" (Ballance and Edmunds), 1891.

[2] *The Lancet*, March 27th, 1897, p. 872, "Complete Longitudinal Division of the Sternum"; "Tuberculous Glands removed successfully." Also *The Lancet*, January 26th, 1901, p. 242, "Silver Tracheotomy Tube removed from the Right Bronchus"; "Death from Sepsis.'

[3] "Annals of Surgery," October, 1901.

pulsation in the aneurysm immediately ceased. The common carotid was next exposed just above the aneurysm; two strands of gold-beater's skin ligature were passed around it and tied in a stay-knot. The artery was distended and not pulsating, but the operation was completed as planned, though it was obvious at the time that the carotid was distended with clot and that its ligature was really needless. The wound was closed in the usual way and dressings were applied. During the operation the wound was swabbed with sterile cotton-wool mops wrung out in warm sterile salt solution. On the patient leaving the theatre there was no pulse in the right radial artery. The left radial pulse was 120 and good. The right half of the face was colder than the left and the left cheek was sweating. The patient had a restless night and in the morning the breathing was laboured and the left radial pulse was 150. In the afternoon left hemiplegia was noticed and he died in the evening.

Necropsy.—April 17th. The aneurysm and great vessels were carefully dissected out, distended under pressure with cacao butter, and placed in formalin for subsequent examination. The right common carotid, right internal carotid, and right middle cerebral arteries were found to be distended with clot (see Fig. 2). The other vessels at the base of the brain were collapsed and contained no clot. There was more subarachnoid fluid than normal. There was no disease found in any other organ. When hardened the aneurysm and great vessels were bisected in a coronal direction. The aneurysm involved the innominate artery with the exception of the lower half inch, the first and second parts of the right subclavian artery, and the origin of the common carotid artery (see Fig. 3). The ligature was seen holding the vessel walls in contact without rupture of the coats.

Remarks.—The case presents many points of interest. A specimen from a case of innominate aneurysm in which the proximal three-quarters of an inch of the artery were free from disease is in the St. Bartholomew's Hospital Museum (No. 1507) (see Fig. 5). It was taken from the body of a girl, aged 20 years, who died from dyspnœa resulting from pressure on the trachea. This case might possibly have been, like the one described in this paper, treated by proximal ligation, and the two cases, together with Farquhar Curtis's successful operation, give some encouragement to the surgeon to attempt proximal ligature since it would appear that the upper part of the artery is more liable to aneurysmal dilatation than the lower, possibly owing to the great strain at the point of bifurcation. The exact condition, of course, can only be determined by operation. According to Scarpa's law, "it is a certain and incontrovertible fact in practical surgery that a complete and *radical* cure of aneurysm cannot be obtained in whatever part of the body this tumour is situated unless the ulcerated, lacerated, or wounded artery from which the aneurysm is derived is by the assistance of nature, or of nature combined with art, obliterated and converted into a perfectly solid ligamentous substance for a certain space above and below the place of the ulceration, laceration, or wound."[1] This is the reason why aneurysm of the arch of the aorta cannot be cured, as obliteration of the aortic arch is incompatible with the continuance of life. The innominate artery may, however, be obliterated without life being thereby destroyed. A specimen numbered

[1] "Scarpa; A Treatise on Aneurysm," translated by Wishart, p. 202.

1501[6] in the Museum of Guy's Hospital shows a large thoracic aneurysm which had completely obliterated the orifices of the innominate and left carotid arteries; the patient lived for a year in fair health without a carotid or a right radial pulse.[1] A case is related in the *Revue de Médecine* of a man, aged 46 years, who had been under observation for about 12 months suffering from attacks of angina pectoris. The innominate artery and the left common carotid were found at the necropsy firmly occluded, not as in the above quoted case from the effects of pressure from without, but as the result of endarteritis obliterans.[2] At the meeting of the Pathological Society of London on Oct. 21st, 1902, Dr. Thursfield showed a very similar specimen of occlusion of the innominate and left carotid arteries.

These cases appear to show that if only the coats of the arteries are not ruptured the great vessels at the root of the neck may be successfully ligated. We need not, therefore, be deterred from attempting to bring about surgical occlusion of the innominate for the cure of innominate aneurysm. Proximal ligature is the only sure means of effecting this obliteration; all other methods are uncertain and less effective.

Published cases.—From the cases cited by Erichsen,[3] H. L. Burrell,[4] and Jacobson[5] it appears that the innominate artery has been tied in 32 instances, five of them being for hæmorrhage. Five only of the 32 cases recovered; in one of these the aneurysm returned 10 years later and then proved fatal, and in another the arrest of pulsation in the aneurysm was only temporary and on the sixty-seventh day the patient died after the first part of the subclavian had been tied as a last resource. The author expresses doubt as to whether he really made a satisfactory ligature of the innominate at the first operation. In the other three cases of recovery the aneurysms are spoken of as "cured," but the record does not extend over two years. In one it is said that 16 months after the operation the aneurysm was a small moveable and hard tumour. All the cases of recovery are described as subclavian aneurysm and one was of traumatic origin.

Subsequently to the publication of these lists I have only found the successful case of Farquhar Curtis previously alluded to. In France and in Germany the operation of ligature of the innominate does not seem to be regarded with much favour, for in the Duplay-Reclus "Treatise on Surgery" the question is dismissed in a few lines with the observation: "That in three cases mentioned by Le Fort in which the operation was attempted it had to be given up as the aneurysm reached too close to the aorta."[6] Bergmann and Mikulicz say: "In aneurysm of the terminal portion of the innominate the commencement of the artery is not sufficiently accessible for proximal ligature on account of the presence of the sac, and in aneurysms of the subclavian or of the carotid ligature of the innominate is contra-indicated because of the danger of grave circulatory disturbances."[7] König writes: "Ligation (of the innominate) cannot absolutely be struck

[1] See "Ligation in Continuity," p. 91.
[2] "Revue de Médecine," tome viii, 3, p. 201 (1888). Article by Déjerine and Huet.
[3] "Science and Art of Surgery," tenth edition.
[4] "Boston Medical and Surgical Journal," August 8th, 1895.
[5] Jacobson and Steward, "The Operations of Surgery," fourth edition.
[6] Duplay and Reclus, "Traité de Chirurgie," vol. v, p. 750.
[7] "Handbuch der Praktischen Chirurgie," vol. ii, p. 43.

out of the list of justifiable operations, for under certain circumstances it may be the only possible means of arresting a haemorrhage. Whether there is any justification for the operation in cases of large aneurysm of the subclavian remains, in spite of the single successful case—that of Smith—very doubtful."[1]

Some anatomical points.—It goes without saying that a clear appreciation of the anatomy of the region is of the first importance in the performance of the operation. "I always determine in my own mind," said the sculptor Chantrey, "the expression to be given, and unless I can see the face distinctly and with that expression when I close my eyes I can do nothing."[2] The position of the great arteries is shown in Fig. 4 and in the drawings of transverse sections of the neck (Figs. 6 and 7), the levels of which are indicated in Fig. 4. Anatomical study shows, therefore, that ligature of the innominate is a cervical operation by no means difficult of performance. There is no risk of injury to the pleura if the vessel be approached from the front and from the tracheal side and if the knife is not used outside the limits of the pulsation area. Moreover, there need be no division of muscular fibres.

Section of the sternum.—For the ligation of the artery this is unnecessary. Curtis's modification of Milton's method is, no doubt, admirably adapted for the exposure of the superior mediastinum, but for the purpose of dealing with the great arteries as they come off from the aorta it is not only unnecessary but inadvisable. The difficulties of the operation are by no means insuperable, and in my case, though it might be thought to have been a matter of great anxiety, I cannot say that the operation was specially difficult. I scarcely like, however, to adopt the "gay comparison"[3] of Sir W. Mitchell Banks, who in contrasting the ligation of the innominate with another operation subsequently performed upon the same patient says that it was "a mere surgical amusement."[4]

Choice of the ligature.—The ligature employed was of gold-beater's skin. This is pure white fibrous tissue and is slowly absorbed from the surface.[5] These ligatures were made for Mr. Edmunds and myself by MacFarlan of Edinburgh. The gold-beater's skin ligature seems to be an appropriate material since it is of white fibrous tissue of which the outer coat of an artery consists. It is strong, inelastic, round, smooth, pliable, and easily tied into a knot, absorbable and yet not too readily so, but it cannot be boiled Floss silk, which possesses the above characteristics, can be boiled and can therefore be certainly sterilised; hence gold-beater's skin ligature cannot be considered superior to floss silk.

Choice of the force.—The force necessary to occlude the innominate artery by means of a stay-knot without rupture of its coats is about three pounds, whereas the force necessary to rupture is about 10 pounds, so that a fairly large margin is allowed, and it should not need a large experience of the ligation of great arteries in order to ligature the innominate without rupture of its coats.

[1] "Lehrbuch der Speciellen Chirurgie," vol. i, p. 54.
[2] H. P. Robinson, "The Studio and What to do in It," p. 49 (1885).
[3] "Antony and Cleopatra," Act iii, scene 2.
[4] Jacobson, *op. cit.*
[5] See Figs. 129 and 130 in "Ligation in Continuity."

Choice of the knot.—The knot adopted was "the stay-knot." It would appear from certain published writings that the method of applying this knot is not clearly understood. The principle upon which the stay-knot depends is that the mutual support which the ligatures afford one another by friction and interlocking prevents the first hitches of the knot slipping when the ends are relaxed, as they must be to complete the reef-knot. The essential part of the stay-knot is therefore the method of applying the first hitches. The best way of tying the stay-knot with two ligatures is to make on each separately, and in the same way, the first hitch of a reef-knot and to tighten each separately so that the loop lies in contact with the vessel without constricting it; then, taking the two ends on one side together in one hand and the two ends on the other side in the other hand, to constrict the vessel sufficiently to occlude it, and finally to complete the reef-knot. The simplest method of completing the knot is to treat the two ends in each hand as a single thread and to tie as if completing a single reef-knot (see Figs. 8 and 9). Three or four ligatures can be employed in this manner; by pulling the ends of the ligatures simultaneously they will lie evenly side by side and constrict a greater length of vessel than if they were tied separately and were lying, as they then might, one on the top of the other in a deep groove in the artery.

The cause of death.—Death was due to extension of thrombosis from the aneurysm to the middle cerebral artery, and the question arises, Is this an inevitable consequence of ligature of the innominate? The case supports in a remarkable way some experiments of Spencer and Horsley on the arrest of hæmorrhage from the middle cerebral artery and its branches. They showed that compression or ligature of the common carotid artery arrested hæmorrhage from the middle cerebral artery and caused anæmia of the brain within its area of distribution. Their experiments led them to suggest the ligature of the common carotid in certain cases of ingravescent apoplexy. Now, it is a remarkable fact that both in Curtis's case and in my own the common carotid was distended, where exposed for ligature, with clot at the time of the operation, but in my case for some reason or other clotting extended upwards while in Curtis's case this extension did not take place. When the common carotid is tied though anæmia of the area supplied by the middle cerebral artery of the same side occurs this condition is a temporary one and we do not anticipate coagulation of the blood in the middle cerebral artery; in fact, coagulation on the distal side of a common carotid ligature is not usually extensive. I have no hesitation whatever in saying that the clotting which caused the death of my patient was not due to a local but to a general condition cause. He was ill-nourished, and in order to attempt the cure of the aneurysm without operation the Valsalvan treatment was adopted, combined with the administration of considerable doses of iodide of potassium. The result was not to produce any effect on the aneurysm, but to bring about a condition of low nutrition and the fatal thrombus was really marantic thrombosis and not a necessary sequel of the operation. Such thrombi are not seldom found in the venous sinuses of children who have died from diseases associated with malnutrition. The treatment therefore previously to operation should not have been starvation but a full and generous diet. Under modern conditions the adoption of the Valsalvan treatment in an operable case of aneurysm is, in my judgment, an error.

Fig. 1.

Drawing of a cast of the patient's neck previously to operation. ($\frac{1}{2}$ Natural size.) The position and size of the aneurysm are well seen.

Fig. 2.

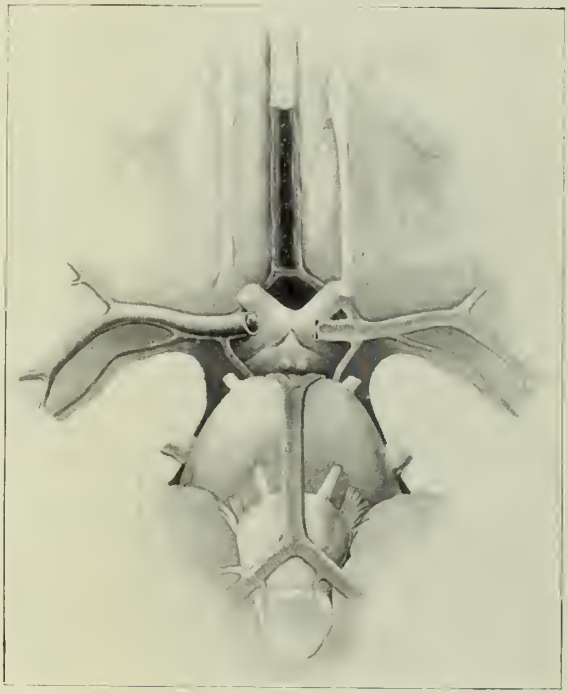


Fig. 3.

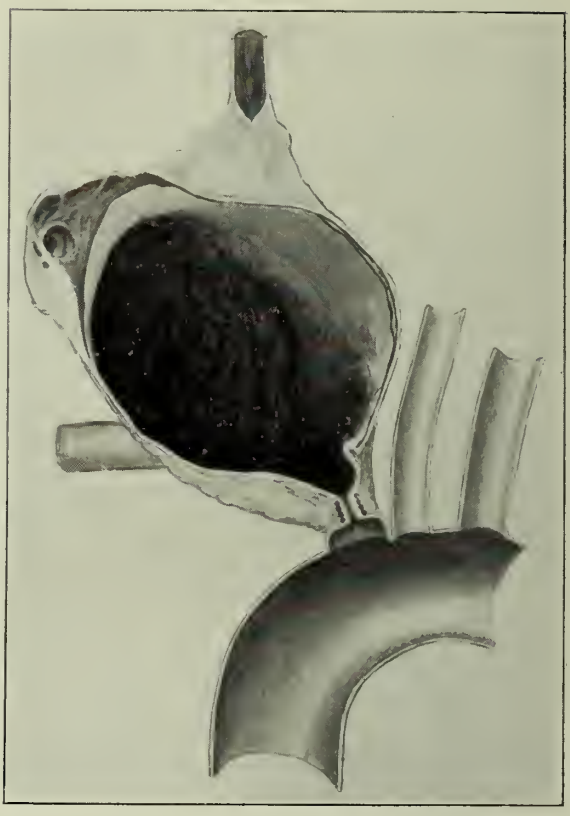


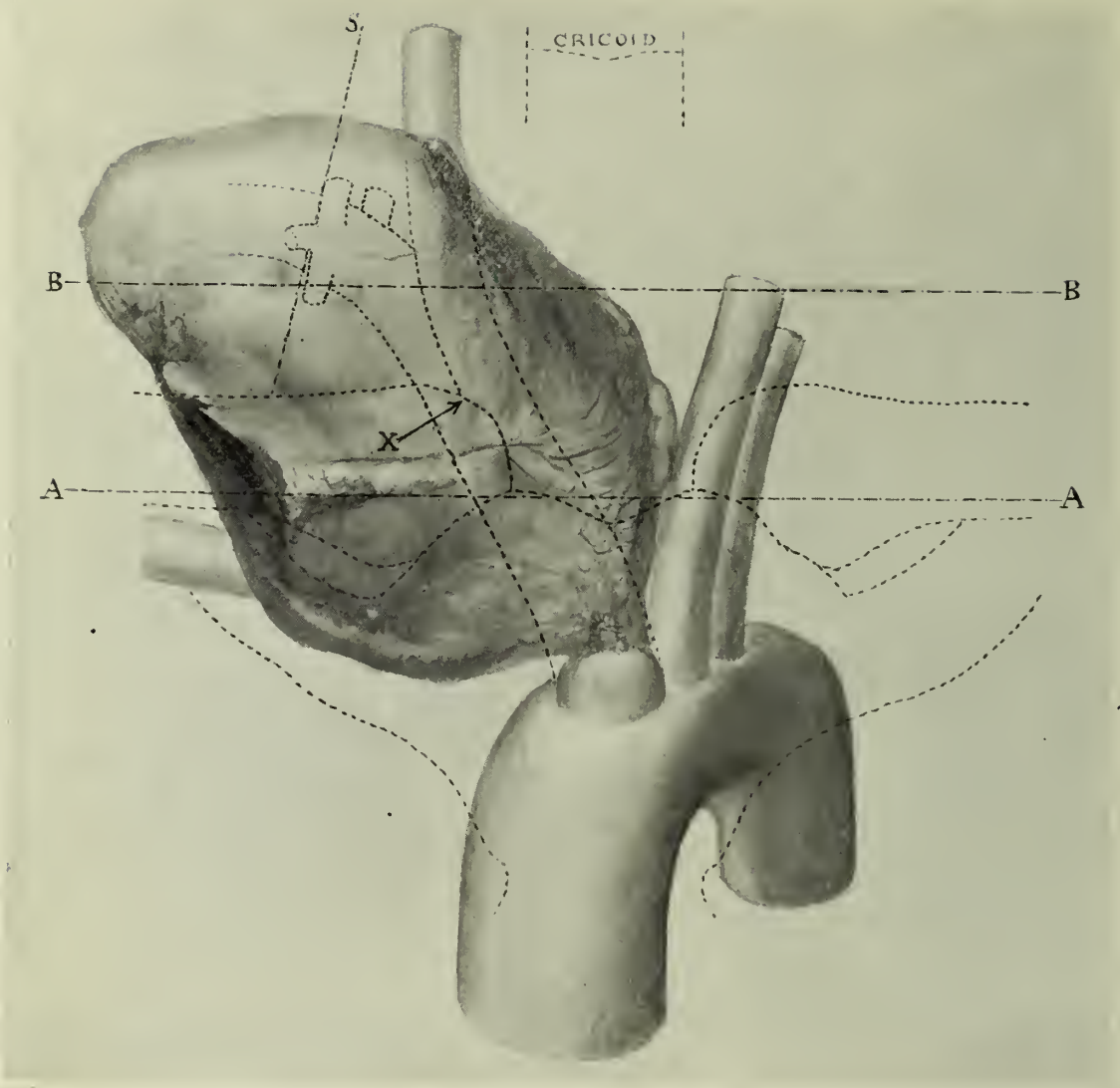
Fig. 2.—Drawing of the base of the brain. (Rather less than two-thirds natural size.) The right middle cerebral artery and its branches are distended with clot. The other arteries are flat and empty.

Fig. 3.—Drawing of a section made in a coronal direction through the middle of the aneurysm and great vessels after hardening. (Rather over one-third natural size.) The arteries had been previously distended under pressure. The four gold-beater's skin ligatures appear in section holding the uninjured coats of the innominate together so that the artery is completely obstructed at the site of ligature. The folds or pleats into which the wall of the artery is thrown on the proximal side of the ligature are evident and also the closeness of the ligature to the aorta below and to the aneurysm above. The aneurysm involves the whole of the innominate with the exception of the proximal half inch, the first and second parts of the right subclavian artery, and the root of the right common carotid. The third part of the right subclavian artery is undilated but is much displaced downwards. The common carotid above the aneurysm is full of clot. The upper and outer part of the aneurysmal wall was the weakest part and it was at this point that the tumour was extending. The aneurysm involves the whole circumference of the vessels and beyond it the arteries are normal.

Fig. 5.

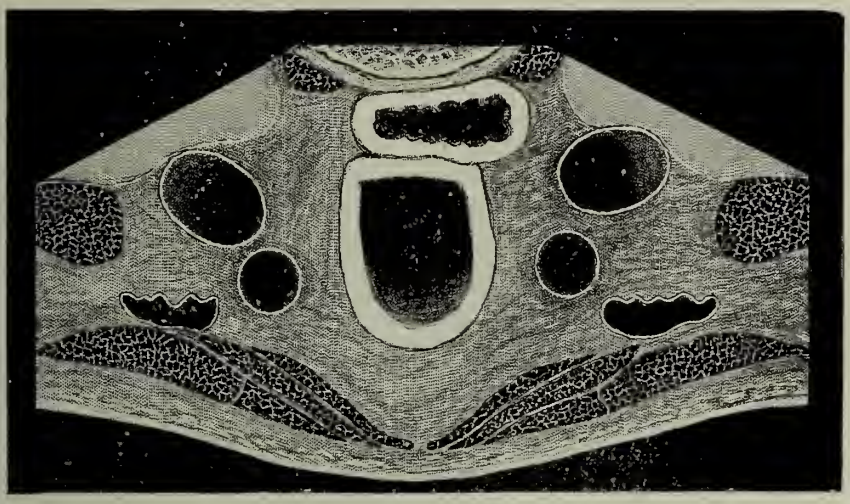
Aneurysm of the innominate artery. (Natural size.) From St. Bartholomew's Hospital Museum, specimen 1507. See also Lawrence, "Transactions of the Royal Medical and Chirurgical Society," vol. vi, p. 227 (1815). The figure is taken from "Ligation in Continuity" (Ballance and Edmunds).

Fig. 4.



Front view of the great arteries and of the bones at the root of the neck shown in outline, together with a sketch of the position of the aneurysm and the site of the ligature of the innominate artery. (Natural size.) The anatomical position of the great arteries at the root of the neck is as indicated when the shoulders are raised and the head is thrown back. The manubrium sterni, the clavicles, and the first ribs are shown by dotted lines, as are also the inner border of the right anterior scalene muscle (S) aad the lower border of the cricoid. The cricoid is nearly two and a half inches (six centimetres) from the sternal notch. The left border of the innominate artery first appears in the neck immediately behind the middle of the episternal notch—that is to say, exactly in the middle line. The bifurcation of the innominate is indicated by the arrow X ; the bifurcation is directly behind what Ward names the superior angle of the inner extremity of the clavicle. The subclavian arises from the back of the innominate and passes upwards, outwards, and also backwards, so that in the drawing it is foreshortened. At the episternal notch the innominate is 1·25 inches (32 millimetres) from the surface. The figure shows that when the innominate is not itself diseased ligation of the vessel would be a cervical and not a mediastinal operation. The lines A A and B B represent the levels at which the transverse sections shown in Figs. 6 and 7 are taken.

Fig. 6.



Transverse section of the neck (½ Natural size) seen from above at the level of the line B B in Fig. 4. This line is half an inch above the clavicle and 1·2 inches above the episternal notch. The section passes below the branches of the first parts of the subclavian arteries. On either side in front is seen the cross section of the sterno-mastoid muscles; a white line separates the sternal from the clavicular origins; behind these are the sterno-hyoid muscles—they do not meet in the middle line at this level; behind these again are the sterno-thyroids; at the outer border of each sterno-hyoid is seen the collapsed jugular vein. In the middle line are the trachea, œsophagus, and vertebral column; on either side of the vertebra the longus colli muscle is seen in cross section; external to this the grey-shaded area represents the section of the apex of the lung and pleura; this is seen as far outwards as the scalenus anticus, which is oval in section. The arteries are represented at their natural (distended) size and the coats with the thickness they have when under the blood pressure during life; the arteries on the right side are a little anterior to those on the left; the subclavian arteries are cut obliquely and the shading shows the direction they are about to take behind the scaleni muscles and over the dome of the pleura which they groove. All other structures are omitted for the sake of clearness.

Fig. 7

Transverse section of the neck (½ Natural size) seen from above at the level of the line A A in Fig. 4. In front on either side of the median line the two white ovals are transverse sections of the tendinous sternal origins of the sterno-mastoids. External to these are in section the two sterno-clavicular joints with their inter-articular cartilages; at the back of the drawing the vertebral column is seen. Behind the bones in front are found the two sterno-thyroids and external to them the sterno-hyoids; behind the sterno-hyoids are the collapsed jugular veins, the left being nearer the median line than the right and overlapping the left carotid artery. To show clearly the position of the main arteries many structures are omitted. The innominate is seen cut obliquely; the shading indicates its direction; the left carotid and left subclavian are cut transversely. The drawing shows that if the innominate artery is approached directly from a median incision there would be no risk of injury to the pleura. The small artery near the jugular vein on each side is the internal mammary. The anterior border of the trachea is 1·4 inches from the surface; the shading shows how the trachea is directed somewhat backwards as well as downwards. Behind and to the left is the œsophagus. On either side (shaded grey) are the lung and pleura. (The drawings of these transverse sections are taken from "Ligation in Continuity.")

Fig. 8.

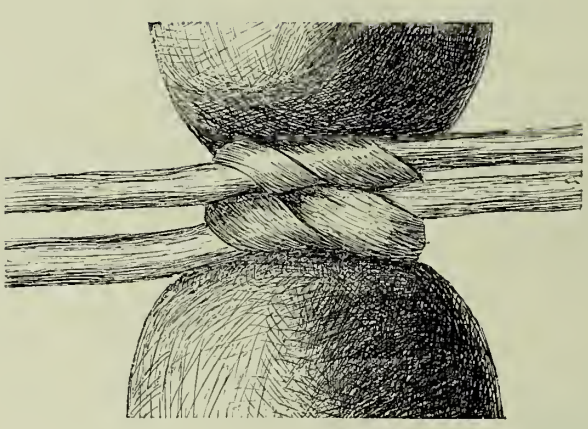
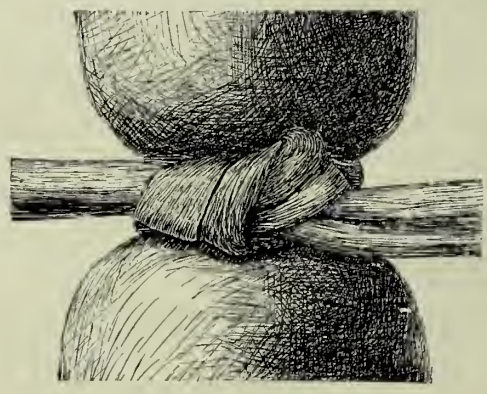


Fig. 9.



Drawings to show the method of tying a stay-knot.

Fig. 8.—The first half of a reef is tied on each ligature in the same way, the two ends on either side being treated as one are drawn upon to occlude the vessel. The hitches lie at the bottom of a deep groove and fit into one another. The friction between the loops and hitches prevents the expansion of the loops and the re-opening of the artery during the time required for the completion of the knot.

Fig. 9.—Shows the knot completed by using the two ends on each side as a single cord and tying the second hitch as if completing an ordinary reef-knot. (The figures are taken from "Ligation in Continuity.")

Harley-street, W.